The Great Lakes Entomologist

Volume 32
Number 3 - Fall 1999 *Number 3 - Fall 1999*

Article 7

October 1999

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DISTRIBUTION OF AN EXOTIC PEST, *AGROMYZA FRONTELLA* (DIPTERA: AGROMYZIDAE), IN MANITOBA, CANADA.

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ABSTRACT

Agromyza frontella is an exotic alfalfa pest from Europe that was first detected in North America in 1968 and has since spread westward into Ontario and the north central United States. Informal surveys had detected *A. frontella* in Manitoba, but its distribution throughout this province was unknown. In 1998 we collected alfalfa stems to detect plant damage and sweep samples to detect adult *A. frontella* and the parasitoid *Dacnusa dryas* throughout the alfalfa growing region of Manitoba. In south central Manitoba, 100% of stems were damaged by *A. frontella*, and > 100 adults/10 sweeps were recorded at several sites. In west central Manitoba, no plants were damaged and < 10 adults/10 sweeps were observed. We believe this region to be near the western edge of *A. frontella* distribution. The most important introduced parasitoid of *A. frontella*, *D. dryas*, was not detected which suggests that *D. dryas* has not invaded Manitoba.

The alfalfa blotch leafminer, *Agromyza frontella* (Rondani) (Diptera: Agromyzidae), is an exotic pest from Europe and was first detected in North America in 1968 (Miller and Jensen 1970). Since its arrival, populations of *A. frontella* have spread westward at a rate of 48–80 km/yr (Hendrickson and Plummer 1983). By 1974 *A. frontella* had been detected in Quebec, eastern Ontario and the Maritime provinces (Harcourt et al. 1988). In eastern Ontario, populations reached levels that warranted insecticide treatments (Harcourt et al. 1987). Reports of the continued spread of *A. frontella* were scarce until 1994, when it was discovered in Minnesota (Hutchison et al. 1997). In 1996, informal surveys detected *A. frontella* in Manitoba, but the distribution of *A. frontella* throughout the province was not determined.

Agromyza frontella appears to have an adverse impact on alfalfa yield and quality (Hendrickson and Plummer 1983). Female flies cause plant damage by puncturing alfalfa leaflets with their ovipositors and feeding on plant juices. The puncture and feeding results in characteristic "pinhole" damage (Bereza 1979). Larvae also damage leaflets by feeding beneath the epidermis of leaves, creating question mark-shaped blotch mines. Yield losses ranging from 7–17% with annual losses of $13 million have been reported in infested areas (Hendrickson and Plummer 1983). Mined leaflets may also incur a reduction in crude protein (Hendrickson and Day 1986).

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In Ontario and the northeastern US, the introduced parasitoid *Dacnusa dryas* (Nixon) (Hymenoptera: Braconidae) has been identified as the most effective biological control agent of *A. frontella* (Hendrickson and Plummer 1983, Drea and Hendrickson 1986, Guppy et al. 1988). After initial releases of *D. dryas*, it was hoped that populations of the parasitoid would prevent or accompany the spread of *A. frontella*. However, there were areas where additional releases of *D. dryas* were required (Hendrickson and Plummer 1983). Alfalfa fields where *A. frontella* has escaped *D. dryas* have incurred high levels of damage (Harcourt et al. 1988). Releases of *D. dryas* into these areas have been successful at reducing pest populations to acceptable levels.

The objectives of this study were to document the current distribution of *A. frontella* and to detect the presence of *D. dryas* in Manitoba. *Agromyza frontella* has successfully invaded regions as far west as western Ontario and Minnesota. For this reason and the known biology of *A. frontella* (summarized in Guppy 1981), we hypothesized that *A. frontella* will establish and integrate into all alfalfa-producing regions of Manitoba. Though *D. dryas* has established in much of the present range of *A. frontella* (e.g., Harcourt et al. 1988), the parasitoid has not yet been detected during the recent expansion of *A. frontella* into Minnesota (Hutchison et al. 1997). The history of *D. dryas* releases and this parasitoid's lower rate of spread relative to *A. frontella* (Hendrickson and Plummer 1983) lead us to hypothesize that *D. dryas* has not yet established in Manitoba. Determining the distribution of *A. frontella* and *D. dryas* in Manitoba is the first step in assessing the risk that this pest poses to alfalfa production in Manitoba.

MATERIALS AND METHODS

Data Collection. Field sampling was conducted from 4–30 July 1998. Sites were arbitrarily selected throughout the alfalfa growing region of southern Manitoba (Fig.1). For each sample site, latitude and longitude were estimated using a hand-held Global Positioning System. The nearest town name was also recorded.

Adult insects were sampled using a 38-cm diameter, circular sweep net. A sample consisted of the contents of 10 sweeps of the alfalfa canopy (e.g., Hutchison et al. 1997). Nine samples were taken for a total of 90 sweeps per site. Each sample was immediately placed into a sealable plastic bag, kept cool and dry, and overnight express-mailed to the University of Minnesota. All samples were kept frozen until processing.

Each sample was examined at 10–50× magnification and separated into three groups: hymenopteran parasitoids, *A. frontella* adults, and other insects. All braconid parasitoids were examined to determine whether they belonged to the genus *Dacnusa* using the key of Marsh et al. (1987). After processing, insects were preserved in 70% ethanol for future identification. Adult *A. frontella* were identified according to Hutchison et al. (1997). Voucher specimens of *A. frontella* adults were deposited in the insect museum, Department of Entomology, University of Minnesota.

Stem samples were taken from each field at the time of sweep sampling. Thirty stems were selected arbitrarily, cut at the soil surface, and placed into a paper bag. Samples were kept cool and dry, and overnight express-mailed to the University of Minnesota. Upon receipt, samples were frozen until processing.

For each stem sample, trifoliates were examined for pinholes (evidence of feeding by adult females) and mines (evidence of *A. frontella* reproduction). If one or more trifoliates contained either pinhole or mining damage on a given

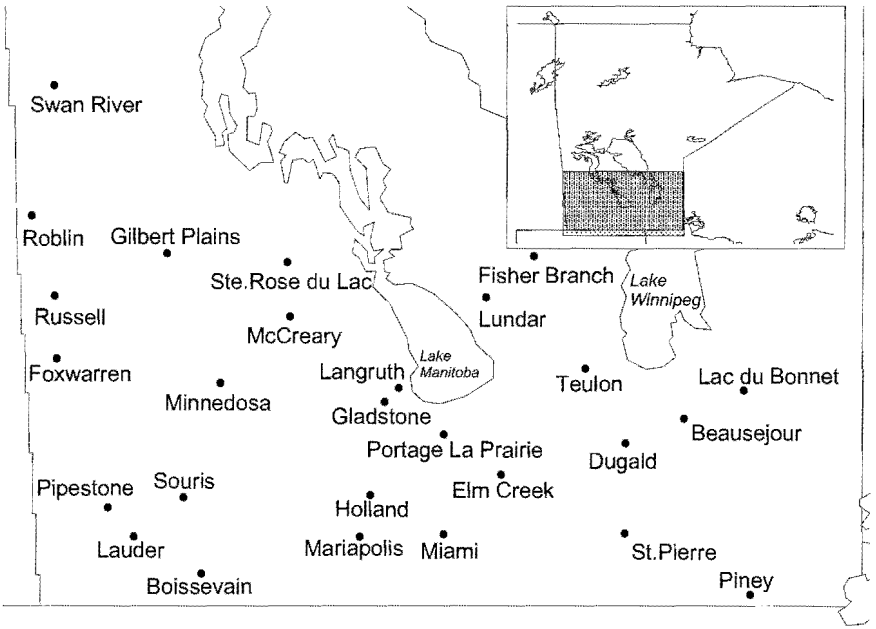

Figure 1. Geographic distribution of alfalfa fields in southern Manitoba sampled for *Agromyza frontella* and the parasitoid, *Dacnusa dryas*.

stem, the stem was classified as damaged. For 10 damaged stems from each site, the number of pinholed trifoliates, number of mined trifoliates and the total number of trifoliates per stem were recorded. For sites where < 10 stems were damaged, trifoliates on all affected stems were examined. In cases where a trifoliate had both mining and pinholing, the trifoliate was recorded only as mined.

Data Analysis. For each site, data from sweep samples were condensed to the mean number of adults per 10 sweeps. The data from plant damage were converted to the mean percent of damaged trifoliates/stem per site. All data were incorporated into a geographically referenced database. Data were imported into Arcview GIS 3.0 (Environmental Systems Research Institute, Redlands CA) to analyze the geographic distribution of adult populations and plant damage. Isoclines between sample locations were generated with Spatial Analyst 1.1 (ESRI, Redlands, CA), and interpolations were created with data from the nearest 8 sites.

To detect regional differences in infestation levels, the sampled region was divided into three sections (Fig. 1): the western section incorporates all sites west of Minnedosa inclusive, the central section is defined as the area between Ste. Rose du Lac and Fisher Branch, and the eastern section incorporates all sites east of Teulon inclusive. Number of adults/10 sweeps, percentage of mined trifoliates/stem and percentage of pinholed trifoliates/stem from all sites in a section were subjected to analysis of variance with means

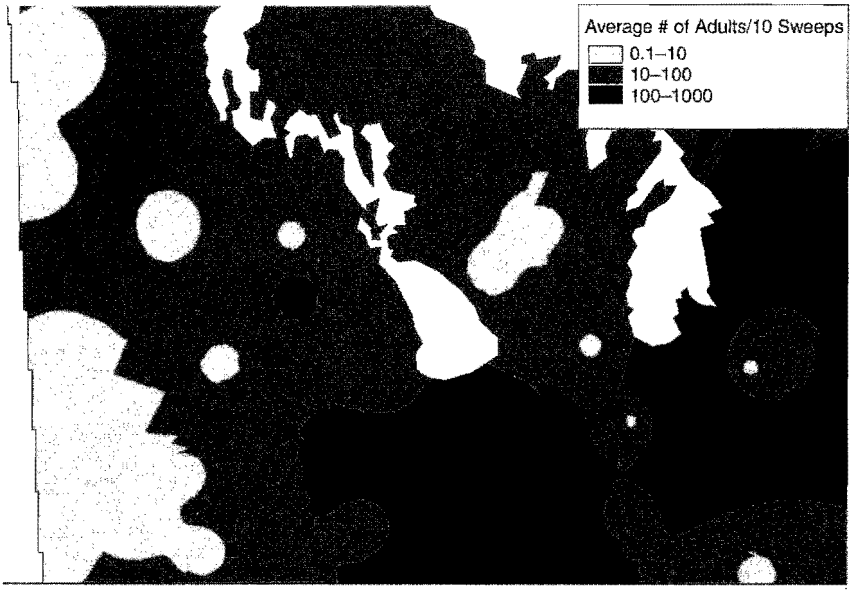

Figure 2. Distribution of *Agromyza frontella* adults in southern Manitoba.

separation by LSD. Data were transformed as necessary to correct for non-homogeneity of variance.

RESULTS

Agromyza frontella adults were detected throughout southern Manitoba (Fig. 2). The highest numbers of adults were in the central third of the sampled region (Table 1), and at Beausejour (597 adults/10 sweeps). The lowest numbers of adults were in the northern and eastern portions of the sampled region. Two samples taken from separate sites near Fisher Branch yielded 0.9 adults/10 sweeps and no adults, respectively. These were the only sites where no adults were observed. *Dacnusa dryas* was not detected in any of the samples.

The percentage of trifoliates with mines was greatest in the central third of the sampled region, reaching 35.5% mined trifoliates/stem at McCreary (Fig. 3). Much of the rest of the sampled region had ≤ 5% mined trifolates/stem. Ten of the sampled sites had no mining damage, and these sites were distributed throughout southern Manitoba. The percentage of stems with pinholes was also most severe in the central third of the sampled region (Fig. 4).

The percentage of stems with pinholes or mines was highest just west of Lake Manitoba (Figs. 3–4). Less than 3%-damaged trifoliates/stem were observed in areas in the northwestern portions of the sampled region and for Dugald. These areas of lowest damage per stem corresponded to areas of lowest adult populations (Fig. 2).

Table 1. Regional comparison of adult densities and plant damage caused by *Agromyza frontella*.

	Western Region*	Central Region	Eastern Region*
Adults/10 sweeps (±SEM)	9.1 ± 3.6A	89.0 ± 29.1A	116.7 ± 97.1A
% mined trifoliates/stem (±SEM)	1.1 ± 0.5A	9.5 ± 3.3B	3.0 ± 1.9AB
% pinholed trifoliates/stem (±SEM)	16.2 ± 5.3ab	33.6 ± 6.3a	11.8 ± 4.2b
n =	10	12	6

* The western region corresponds to the area west of Minnedosa, and the eastern region includes the area east of Teulon.
Means within rows followed by the same letter are not statistically different as determined by analysis of variance and LSD (capital letter: $\alpha = 0.1$; lowercase letter: $\alpha = 0.05$). To conform with assumptions of ANOVA, adult counts and percentage of trifoliates with mines were transformed following log10(Y+1) and ARCSIN(SQRT(Y/100)), respectively. Transformed data not shown.

DISCUSSION

We believe the geographical distribution of adult counts and plant damage in Manitoba reflects the initial phases of the invasion process. Vermeij (1996) describes an ecological invasion in four stages: arrival, establishment, integration, and spread. Arrival involves the dispersal of individuals into a recipient region; establishment occurs when a population is maintained through local reproduction; integration occurs as the invader and recipient

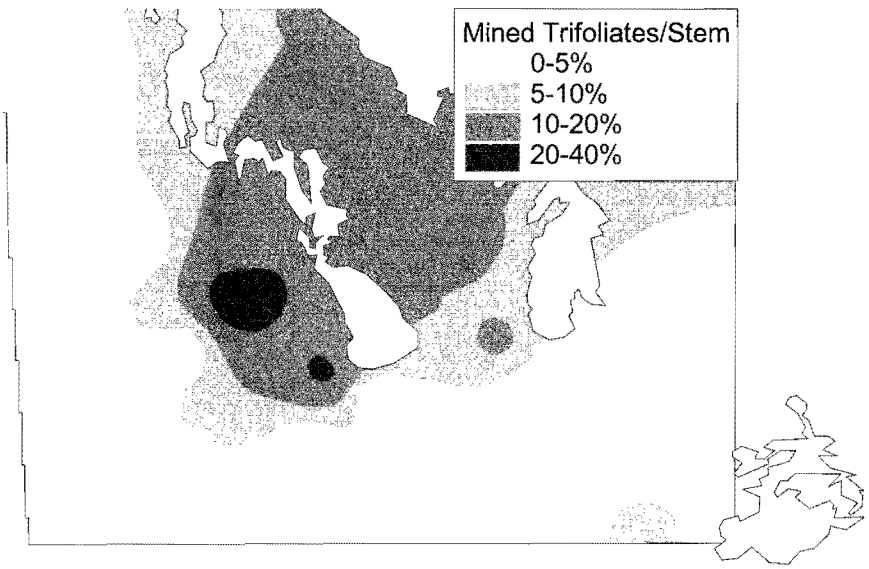

Figure 3. Percentage of trifoliates on 30 alfalfa stems with ≥ 1 *Agromyza frontella* mine in southern Manitoba.

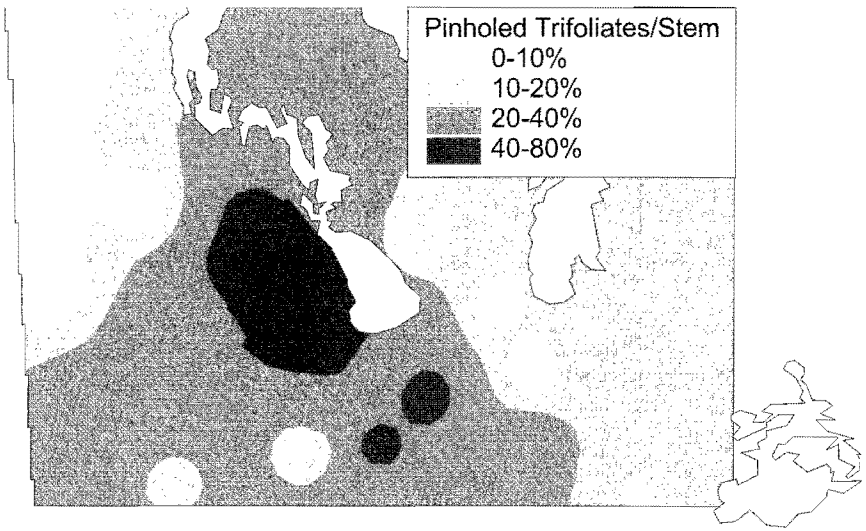

Figure 4. Percentage of trifoliates on 30 alfalfa stems with ≥ 1 *Agromyza frontella* pinholes in southern Manitoba.

biota adapt to each other; and spread is the local dissemination of individuals from integrated populations into adjacent habitats or regions. Though the invasion process is a continuum, these divisions are useful in examining demographic trends. Our results suggest that *A. frontella* has passed through the arrival stage and is in the establishment stage throughout southern Manitoba.

For populations in the establishment stage we would expect to detect mining, adult populations and pinholing levels. The phenomena associated with the establishment stage appear to be most evident in the central portion of the sampled region. Level of mining in the central third of the sampled region is significantly higher than the western third suggesting populations of *A. frontella* have been established in south-central Manitoba longer than in south-western Manitoba.

Geographic regions possessing adult populations that are not yet reproducing may be in the arrival stage. For areas where *A. frontella* had recently arrived, we would expect to see a lower ratio of mines/adult. Though the western third of the sampled region exhibits only 1.1% mined trifoliates/stem (Table 1), the number of adults is proportionally lower, and the ratio of mines/adult is not significantly different from the central third. It is likely that the western third of the sampled region is a younger infestation, but our data suggests that *A. frontella* is currently established in southwestern Manitoba.

The mechanisms for the lower level of pinholing in the eastern region relative to the central region (Table 1) and increased variance in adult numbers within the eastern sites (Table 1) are unknown. Processes associated with the latter part of the establishment (Brown 1993) and/or integration stages may explain the patterns observed in the eastern region. Different environ-

mental restrictions (climatic or habitat quality) and levels of biotic resistance between sites are likely to become more evident in the latter stages of invasion. For the integration stage we might also expect to discern genetic adaptation of *A. frontella* populations in response to local environments.

We recognize that a single sample from a field does not completely describe local population dynamics, and we caution readers not to interpret divisions of population densities represented in our maps too literally. However, our sampling strategy does provide a "snapshot" of a continually evolving process. Further studies to assess the impact of *A. frontella* on alfalfa yield and quality are required to determine the possible implications that *A. frontella* may have for Manitoba alfalfa producers.

ACKNOWLEDGMENTS

We thank Kelly Dingmann, Katie Gore, Markeeta Keyes, Rebecca Radintz, Katie Vogt, and Suzanne Wold for processing samples. We also thank John Heard for his early contributions to sampling efforts; Tim Friesen for assisting in sample collection in 1998; John Luhman for initial identification of *Agromyza frontella*; and the University of Minnesota Agricultural Experiment Station, the North Central IPM Program, and the Minnesota Department of Agriculture for funding components of this project. This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or recommendation for its use by the USDA. This is publication 99–117–0010 of the Minnesota Agricultural Experiment Station.

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